Gender Evolution in Strawberries

The Doorway to Enhanced Productivity

It's no surprise that strawberries are the most popular type of berry fruit in the world. This sweet, juicy, refreshing fruit is the perfect snack or end to any meal, especially on a hot summer day. But have you ever wished you could eat locally grown strawberries all year round? Well, new Agricultural Research Service research brings us one step closer.

Kim Lewers, a plant geneticist with the ARS Genetic Improvement of Fruits and Vegetables Laboratory in Beltsville, Maryland, and plant evolutionary ecologist Tia-Lynn Ashman, a colleague from the University of Pittsburgh's School of Arts and Sciences, discovered a model system for studying sex chromosomes in plants. This discovery opens up new opportunities for developing novel strawberry cultivars with increased fruit yields all year long.

Lewers and Ashman set out to determine the genetic control of reproductive dysfunction in strawberries because of its importance to fruit yield and quality. Reproductive dysfunction occurs when strawberry flowers do not bear fruit or do not produce enough pollen, resulting in small, misshapen fruit.

Strawberry breeders have long believed that strawberry plants can have one of three reproductive functions: male, female, or hermaphrodite. Male plants bear flowers that produce pollen but cannot set fruit. Female plants produce fruit if their flowers are pollinated, but cannot produce their own pollen. Hermaphrodites contain both male and female functions that enable them to flower, self-pollinate, and bear fruit. According to Lewers, strawberry farmers prefer their plants to be hermaphroditic so they don't have to plant more than one kind of strawberry in the same field in order to have any fruit to harvest.

Many breeders also follow the theory that genetic control of gender in strawberry plants is determined by one gene, and that there are three forms of the gene—scientifically referred to as "alleles"—at a single location on the chromosome that determines a plant's gender. According to this theory, the female allele is dominant, the hermaphrodite is semidominant, and the male allele is recessive.

Researcher Ashman collected plants of the wild strawberry *Fragaria virginiana* and crossbred them to create 200 offspring plants in hopes of better understanding the inheritance of dysfunction. "As our research progressed," says Lewers, "I began to wonder, 'What if dysfunction is determined by two separate loci, the places on a chromosome where a specific gene is located?'"

STEPHEN AUSMUS (D1487-23)

In a research field at Beltsville, Maryland, geneticist Kim Lewers checks for pollen production in strawberry plants.

A New Gender Class

In order to answer her question, Lewers had to examine the data piece by piece. The team first inspected the offspring, giving each plant a score based on its "maleness" or "femaleness." Males were scored "male fertile" if they produced plump, yellow, pollen-filled anthers; those that did not have pollen were scored "male sterile." Similarly, plants were scored "female fertile" when at least 5 percent of their flowers set fruit, while "female sterile" plants bore less than 5 percent fruit. Plants with strong male and female traits physically demonstrate the dominant sex alleles in their DNA.

The next step involved mapping the genes that control reproductive dysfunction in *F. virginiana*. Genetic mapping is a process by which geneticists determine which genes are next to each other and, therefore, are usually inherited together. The

TIA-LYNN ASHMAN (D1490-1)

Plants that have no pollen and cannot produce fruit, even when pollinated, are neuter.

TIA-LYNN ASHMAN (D1488-1)

Plants without pollen that can set fruit if pollinated by another plant are female.

closer together the genes are, the higher the chances of their being inherited together. The process can include physical traits, like reproductive dysfunction, and molecular markers—tools geneticists use as DNA place marks or reference points.

Lewers, Ashman, and Ashman's postdoctoral fellow Rachel Spigler were able to create the first reproducible molecular-marker map of an octoploid strawberry. Most strawberries sold in grocery stores are octoploids—meaning in their natural evolution, the chromosomes have doubled and then doubled again to produce their current genetic makeup. The map the researchers produced can be used by strawberry breeders to help them naturally breed strawberries with better traits, such as disease resistance and year-round fruiting.

Two Genes are Better Than One

Lewers also found that gender in strawberries is determined by two genes instead of one, and that the different alleles of the genes tend to be inherited together or passed to the offspring in pairs as they exist in the parents; this means they are physically next to each other on the chromosome.

The DNA map of the offspring shows that recombination—a process where chromosomes cross over and produce combinations of genes not found in the parents—occurs. This results in the presence of neuters, a gender class not taken into account by the conventional theory. Neither male nor female in function, neuters occur when the alleles containing male sterility and female sterility combine. Neuters physically look like females in that they flower and do not possess pollen; however, they do not produce fruit when pollinated.

"What we found is really quite extraordinary," says Lewers. "Before, neuters were not thought of as a possible gender class in strawberry. Our discovery of neuters shows that two loci control gender expression, not one, which means that this strawberry represents a very early stage in the evolution of chromosomes controlling gender in all plants."

Lewers's and Ashman's findings show that the gender determination in strawberries is influenced by two genes with different alleles of each gene on the chromosome. The presence of neuters in the offspring confirms that the two genes can recombine, a key step that has never before been addressed by the traditional theory on strawberry reproduction.

Lewers hopes to use this new research in breeding new strawberry cultivars. Her discovery will help her determine how many seedlings she must grow from crosses involving male or female strawberry parents in order to identify at least some hermaphroditic offspring that contain additional desired traits sought by breeders, farmers, and consumers. This will bring her one step closer to her overall goal: to develop improved disease-resistant strawberry plants that will help farmers grow delicious strawberry fruit for consumers all year long.—By **Stephanie Yao,** ARS.

This research is part of Plant Genetic Resources, Genomics, and Genetic Improvement (#301) and Plant Biological and Molecular Processes (#302), two ARS national programs described on the World Wide Web at www.nps.ars.usda.gov.

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